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Reservoir Recovery Maximization In SEK: Using Pulsar Technology Application

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ABSTRACT

Kuwait Oil Company possess challenges in regulating oil production and rising water cut in many horizontal and deviated wells. Quantitatively, KOC has a current forecast of a water cut of 45-50% for various assets; hence, water management poses a severe issue for future development. In southeast Kuwait specifically, some wells are at a water cut of 90% at the initial target in the Burgan field. KOC has started an initiative to install in-flow control devices (ICD) to optimize the completion strategy in horizontal wells from these clastic reservoirs to address these issues. However, with the rise in water cut, they have taken a novel approach to foresee the potential pay zones of the formations above the target reservoir, which were traditionally overlooked. However, there needs to be more data across these intervals. Therefore, the proposed solution to this challenge was to adopt an advanced cased

hole neutron tool (APNL) to provide a behind-casing reliable formation evaluation to characterize these formations, pinpoint the bypassed oil, monitor water movement, and unlock the potential of these reservoirs. Thus, maximizes reservoir production and gains knowledge for precise future reservoir monitoring.

The new pulsed measurement tool addresses completion challenges like logging through various hole sizes (12.25- and 8.5- inch holes), tubing and dual casing intervals. The robust results provided the main answers to reservoir characterization, which are, a) Lithology: through the APNL high resolution spectrolith processing to provide elemental yields and detailed mineral concentrations in the shaly sands as well as the TOC from inelastic and capture spectroscopy, which is not feasible with previous generation slim tools, b) Total porosity: which is self-compensated for identifying the pore space within these potential zones of interest, and c) Hydrocarbon saturation: either self-compensated sigma-derived, C/O optimization or TOC-derived which exhibited an agreement of the presence of oil with a saturation ranging from 50 to 80% across some of the shaly sand intervals (Rose, D., Zhou, T., Beekman, S. et al. 2015).

A new strategy will be illustrated to maximize reservoir recovery utilizing high-end technology, adopting a new workflow that will help overcome the difficulties, gradually reducing the high water cut to achieve a robust reservoir characterization. Thus, comprehensive formation evaluation is achieved in the cased hole sections that will unlock potential pay zones and allow enhanced future reservoir planning.

EXTENDED ABSTRACT

Greater Burgan field is the heart of Kuwait, contributing to 60 percent of Kuwait's production. Production from greater Burgan started 60 years ago and has remained significant. It contains three main sub fields known as Ahmadi, Magwaa and Burgan. Most of the production is from cretaceous Wara and Upper Burgan formations which are mainly clastic reservoirs of shaly sands, in between there lies a tight carbonate formation called Maudood. Middle Burgan reservoir production is supported by active aquifers with high water support unlike Wara and Upper Burgan. Thus, bypassed oil is often present due to different depletion which needs to be accurately captured.

Greater Burgan field is located in southeast of Kuwait's mature region, where there is significant reservoir potential. However, with the development of the field, the water level rise has become one of the significant challenges that needs to be addressed. Many techniques are utilized to ensure reservoir efficiency and development. Nowadays, Kuwait Oil Company is working effectively towards improving oil production strategy in these mature fields utilizing new techniques. However, different reservoirs have different properties and situations where existing workflows may or may not be suitable for these reservoirs.

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A new approach has been deployed to maximize reservoir recovery in the Burgan field. Evaluating the shallower sections of potential reservoirs in multiple wells is the main objective illustrated here to enhance oil production using new cased hole technology within the clastic formations of Wara and upper Burgan reservoirs. In addition, monitoring water movement as a source of energy is a primary factor which will help in enhancing reservoir performance. Comprehensive workflows are presented to characterize the reservoirs to tap into new potential reservoirs adding to the resources within Burgan field. In addition, the petrophysical model for Burgan reservoir is underestimated which lacks advanced reservoir characterization and formation evaluation leading to underestimation of reserves affecting the economics of the company. As a result, a full petrophysical evaluation is required to obtain a comprehensive reservoir monitoring plan and to capture the bypassed oil in the reservoirs which are not yet targeted. Thus, cased hole advanced (APNL) neutron technology with a slim diameter can play a considerable role in fitting most completion restrictions and detecting un-swept hydrocarbon. It could be directly logged in open hole or after casing and cementing in cased hole wellbores to enhance production while saving operational time and effort. Moreover, logging through tubing and reducing the uncertainty of the reservoirs covered by complex completions can be achieved.

Cased hole wells are challenging environments; a new cased hole tool with a new interpretation method will be illustrated to overcome the difficulties of achieving a solid formation evaluation environment. The new advanced cased hole tool utilized in this study

consists of an electronic pulsed neutron source and four detectors, including a compact neutron monitor, far and near LaBr detectors and the deep YAP detector, which makes it attractive due to the ability of neutrons to penetrate through the completion and the formation, especially to detect oil through tubing and casing. In addition, the fast neutron cross-section measurement (FNXS) can be used to confirm the presence of gas as it is sensitive to gas volume which can help in identifying gas saturation in cased hole to differentiate tight formations from gas filled formations in the absence of open hole porosity in various complex environmental conditions (Rose, D., Zhou, T., Beekman, S. et al. 2015). Moreover, the technology combines several measurements, including spectroscopy with total organic carbon, total neutron porosity, sigma, carbon oxygen ratio and fast neutron cross-section, which can be run all together in Hybrid mode in a single pass.

Due to the limitation of the previous conventional way of evaluation used in Burgan field depending on the reservoir studies from offset wells or on open hole data in the initial stages, there was a challenge in reservoir characterization. This was done when the wells went through multiple changes, where comes the need for a detailed assessment and further evaluation to retrieve what was missed from open hole data. Enhanced reservoir characterization has been achieved on the clastic reservoirs including intensive petrophysical volumetric analysis to identify potential oil zones.

New workflow has been applied to obtain minerology, porosity, sigma cross section analysis and oil volume computation by multiple measurements to confirm presence of hydrocarbon in the clastic reservoirs of Burgan field in Kuwait.

Many challenges need to be considered to achieve maximum reservoir enhancement precisely. One of the main challenges in Burgan is the water cut challenge, which needs management of influent water, shutoff, encroachment, and water filtration. In addition, the lack of open hole data is a critical challenge as many of the wells are old, lack formation evaluation or old tools have been utilized, providing less accurate results that require more effort to achieve efficient reservoir characterization. Moreover, lithology is highly variable, with upper Burgan and Wara being mainly clean and clay-dominant sands, whereas Maudood is a tight carbonate, requiring precise mineralogy output for proper evaluation. Another critical issue is the different formation water salinities. Combined with the complex lithology, these challenges lead to an underestimation of Burgan reservoir hydrocarbon saturation, resulting in a loss in the number of oil barrels affecting the company's economy.

In addition, poor sweep efficiency leads to bypassed oil, a substantial challenge that needs consideration to enhance production and increase reserves. Moreover, complex completion is required due to surface conditions where a need for double casing, inflow control device completion or even tubing requires a slim cased hole tool for evaluation. Different borehole profiles are utilized where vertical wells' completion differs from the completion of the horizontal wells where in many cases, it requires inflow control devices for completion.

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The utilization of cased hole neutron technology including advanced workflow in an integrated way has been illustrated to improve the diagnosis of bypassed hydrocarbon by achieving further formation evaluation in SEK. Different applications have been implemented in SEK to overcome multiple Burgan reservoir challenges such as high-resolution spectroscopy measurement, to identify the mineralogical output in Burgan field and rock composition in detail for carbonate and clastic reservoirs. In addition, an estimation of the total organic carbon volume is obtained and total porosity measurement has been determined using advanced workflow. Thus, high resolution of reservoir quality and completion quality is achieved in various complex environmental conditions.

Moreover, saturation is computed in three ways, either from sigma measurement, which is a result of neutron capture cross-section calculation due to the decay of thermal neutrons in case of saline water with high chlorine content, or from carbon-oxygen measurements (C/O) which allows computing the saturation independent of salinity in cases where formation water salinity is too low, variable and/or unknown. The third way to obtain saturation is from the total organic carbon as the total organic carbon and carbon-oxygen measurement (C/O) are independent of salinity. As a result, hydrocarbon fluid analysis is achieved in any formation water salinity. Thus, combining integrated measurements ensures an efficient and robust evaluation of oil saturation from the Greater Burgan field. In addition, accurate reservoir monitoring is achieved, an increase in the reserves is obtained, and further field development opportunities can be uncovered with high certainty.

A complete petrophysical formation evaluation has been executed, and an advanced answer product has been illustrated. The main goal is to identify lithology in the target reservoirs using the advanced cased hole neutron (APNL) technology measurements without relying on previous open hole data or uncertain parameters like formation water salinity. In addition, bypassed oil has been located and thus pay zones are gained. As a result, new perforation target zones can be efficiently and carefully chosen. Water movement has been observed across all the wells, which helps reducing the high water cut and provided better further reservoir decisions.

In this case study, the well was drilled with water-based mud in Burgan field and logged in a zone above the current perforations. The target reservoir consists mainly of clean sandstone and a small amount of shale. The APNL was logged using GSH-Lith mode in the horizontal development well with dual casing in clastic formation. The main objective of this logging was to determine bypassed oil potential along the target zone Burgan sand upper (BGSU) after workover, identify fluid contact and to obtain petrophysical evaluation in the cased hole section. Open hole data including lithology and porosity were uncertain. As a result, comprehensive lithology output was obtained from the high-resolution spectroscopy analysis. In addition, in-situ total organic carbon (TOC) was computed to obtain efficient oil saturation (Miles et al. 2014).

Porosity and sigma were obtained independently. The computed total porosity ranges from 22 p.u. to 35 p.u as shown in figure 1, and the computed oil saturation increases up to 80% as

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shown in figure 1. Oil saturation obtained from the total organic carbon (TOC) was to confirm the presence of hydrocarbon in the zone of interest as shown in figure 1. In areas where porosity is high, and sigma is decreasing gradually reading less than 18 cu there is a confirmation of hydrocarbon from TOC measurement. In addition, there is a gradual reduction in water saturation to 30% in the zone of interest which is presented in figure 1. APNL advanced interpretation approach helped defining water movement, identifying bypassed pay zones and oil water contact. Thus, a full petrophysical cased hole measurement evaluation was achieved which led to efficient reservoir characterization enabling high certainty for further completion decision.

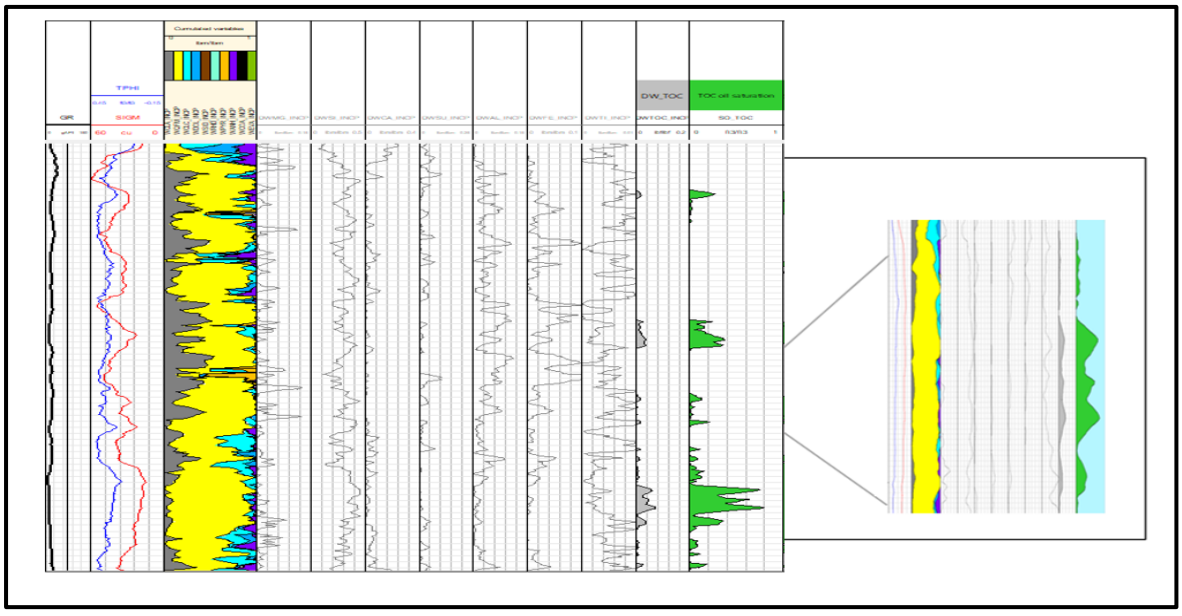

Figure 1: APNL processing result including porosity, sigma, minerology, and oil saturation computed from both total organic carbon and sigma measurements; Track 1- Gamma Ray; Track 2-Total porosity, Sigma; Track 3-Minerology; Track 4-Magnesium weight fraction;

Track 5-Silicon weight fraction; Track 6-Calcium weight fraction; Track 7- Sulfur weight fraction; Track 8-Aluminium weight fraction; Track9-Iron weight fraction, Track 10-Titanium weight fraction; Track 11-Total organic carbon weight fraction; Track 12-Oil Volume from TOC

Kuwait Oil Company and Southeast Kuwait are one step closer to unlocking reservoirs challenges by improving the understanding of the formation petrophysical properties. A comprehensive and flexible workflow has been developed utilizing the state-of-the-art of the cased hole neutron technology to overcome Burgan challenges enabling better reservoir characterization.

By combining all the measurements from an advanced cased hole neutron technology, a sand alone cased hole formation evaluation has been achieved on the shallower reservoir sections of the Burgan field. Efficient monitoring of water movement is obtained by determining fluid contact and enabling better future completion decision leading to reduction of the present high water cut.

Interpretation implemented previously with open-hole data only is now enabled through cased-hole and to address complex challenges to increase the reservoir's efficiency and improve future development plans. Thus, reservoir recovery maximization is achieved, operational effort and cost is reduced, and precise strategy can be adopted for additional reserves growth.